BIOGAS PRODUCTION FROM *BENINCASA HISPIDA* WASTE

NOOR FIZA ASIQIN BINTI MOHD RAMLAN

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Faculty of Chemical and Natural Resources Engineering

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ABSTRACT

Biogas is the mixture of gaseous that generated from the decomposition of organic matter in the absence of oxygen. It consists of methane, carbon dioxide, hydrogen and traces level of other gases. Agricultural wastes where available abundantly in Malaysia serve as one of the potential carbon sources to be utilize to produce biogas.Various sources of agricultural wastes had been investigated their potential in producing biogas. This work will focus on the utilization of *Benincasa hispida* or also known as Kundur and its potential to produce biogas with cow dung slurry as inoculum. Characterization of Kundur wastes and cow dung slurry for TS, TVS, initial pH, COD and NH_3-N are studied. This work also focused on the determination of optimum composition of Kundur waste for the anaerobic digestion. The study was carry out in 2L digester at mesophilic temperature range with total solid concentration of 10% TS and inital pH of about 7. Percent composition of sample A(100wt % Kundur waste) , B(80 wt % Kundur waste:20 wt % Cow dung) , C(60 wt % Kundur waste:40 wt % Cow dung), D(50 wt % Kundur waste:50 wt % Cow dung) and E(40 wt % Kundur waste:60 wt % Cow dung) were used. Sample D shown the most suitable composition with the highest biogas yield of 2.34ml/gTS followed by sample C of 1.46ml/gTS, sample E of 1.16mg/gTS, sample B of 0.3ml/gTS while sample A shown no production of biogas. The different compositions of Kundur waste and cow dung in anaerobic digestion influenced the total biogas production. This lead to a new degree of information Kundur waste are suitable to be used as substrate for biogas generation with the addition of cow dung as inoculum.

PENGHASILAN BIOGAS DARIPADA SISA BUANGAN *BENINCASA HISPIDA*

ABSTRAK

Biogas adalah campuran gas yang dihasilkan daripada penguraian bahan organik dalam ketiadaan oksigen. Ia terdiri daripada gas metana, karbon dioksida, hidrogen dan gas-gas lain. Sisa pertanian di mana tersedia dengan banyaknya di Malaysia berkhidmat sebagai salah satu sumber karbon yang berpotensi untuk digunakan sebagai sumber untuk menghasilkan biogas. Pelbagai sumber daripada buangan industri pertanian telah dikaji potensi mereka dalam menghasilkan biogas. Kajian ini akan memfokuskan potensi terhadap penggunaan sisa *Benincasa hispida* ataupun lebih dikenali sebagai Kundur untuk penghasilan biogas bersama penggunaan tahi lembu sebagai sumber inokulum. Pencirian sisa Kundur untuk analisis TS, TVS, pH awal, COD dan NH3-N telah dikaji. Kajian ini juga tertumpu kepada penentuan komposisi sisa Kundur yang paling optimum untuk pencernaan anaerobik. Kajian telah dijalankan di dalam kelalang 2L pada suhu mesophilik dengan kepekatan jumlah pepejal 10% dan pH awal sekitar 7. Peratusan komposisi sampel A (100% sisa Kundur), B (80% sisa Kundur: 20% tahi lembu), C (60% sisa Kundur: 40% tahi lembu), D (50% sisa Kundur :50% tahi lembu) dan E (40% sisa Kundur: 60% tahi lembu) telah digunakan. Sampel D menunjukkan komposisi yang paling sesuai dengan hasil biogas tertinggi 2.34ml/gTS diikuti oleh sampel C 1.46ml/gTS, sampel E 1.16mg/gTS, sampel B 0.3ml/gTS dan sampel A menunjukkan tiada pengeluaran biogas. Penggunaan komposisi yang berbeza bagi sisa Kundur dan tahi lembu dalam pencernaan anaerobik dilihat mempengaruhi jumlah pengeluaran biogas. Ini menunjukkan bahawa sisa Kundur adalah sesuai untuk digunakan sebagai sumber sebagai penghasilan biogas dengan penambahan tahi lembu sebagai sumber inokulum.

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LIST OF SYMBOLS

%	Percentage
g/VS^{-1}	Gram over volatile solid
kg	Kilogram
KW	Kilowatt
mg	Milligram
Mg/L	Milligram over liter
ml	Milliliter
ml/gTS	Milliliter over gram Total Solid
MW	Megawatt
^{o}C	Degree Celsius
U.l/gm	Unit liter over gram
wt%	Weight percent

LIST OF ABBREVIATIONS

AD	Anaerobic Digestion
CD	Cow Dung
CH_4	Methane
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
EPA	Environment Protection Agency
H_2	Hydrogen
H_2S	Hydrogen Sulphide
HCl	Hydrochloric Acid
HRT	Hydraulic Retention Time
INQ	Index Nutritional Quality
K	Kundur
MHLG	Ministry of Housing and Local Government
MSW	Municipal Solid Waste
N_2	Nitrogen
NaOH	Sodium Hydroxide
NH_3	Ammonia
NH_3-N	Ammonia-Nitrate
TS	Total Solid
TVS	Total Volatile Solid
US	United State
VFA	Volatile Fatty Acid

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Waste is defined as the eliminated or discarded substance or materials or by-product from the completion of a process as they no longer useful. During the olden time, the wastes generated is low and bring less environmental effects occurs as the human population and the activities of industrialization is minimal. However, abundant of waste nowadays from various industry such as agricultural, forestry, municipal market waste, food processing industries, etc., constitute a large and serious environmental burden to the places all over the world. In Peninsular Malaysia, there was approximately 4.2 million tons of crop excesses including vegetables and fruits waste while there is around 2.3 million tons of livestock waste were produced (Lim, 1992). As for other country such as in India reported by Banu et al. (2007), production of fruits in India is estimated to be over 60 x 10^6 tons annually and 40% portion of the fruits are lost as result from the inadequate transport, low storage qualities and marketing. Those wastes are disposed of in an uneconomical and less friendly ways which create a huge pollution problem in the country. This supported by Bouallagui et al. (2005) where other country such as Tunisia also constitute really huge amount of waste from fruit and vegetables and become the source of nuisance in municipal landfill and less effective disposal process.

In common practice in organic solid waste management from the agriculture sectors and livestock farm, the wastes commonly are transported to the landfill to be thrown away. Other than that, incineration is the other method where the process of combustion of the organic matter into ash takes place. However, as according to the Ministry of Housing and Local Government (MHLG), the majority of all 112 landfills in Malaysia are almost at its full capacity. On the other hand, incineration process releases odor emissions and bad for human health. Alternatively, there is one green way to converting the wastes into something valuable for human being which is anaerobic digestion. Anaerobic treatment encompasses of decomposition of organic material in the absence oxygen to produce gases such as methane, carbon dioxide, ammonia and traces of other gases and organic acids of low molecular weight (Abu Bakar and Ismail, 2012).

Fruits waste have much easily digestible carbohydrate and this represent the potential substrate or feed for production of biogas such as hydrogen (H_2), carbon dioxide (CO_2) and methane (CH_4) through anaerobic digestion (Zajic et al., 1979). In recent years, researchers have been attracted to study the anaerobic treatment of fruit wastes and other types of biomass as in Figure 1.1, to generate biogas such as H_2

and CH_4 because it involve treating the wastes into more stabilized form and generate useful products. Apart from that, this process not only provides renewable sources of energy that can be used as electricity or cooking but produce excellent organic manure (Mallick et al., 2009).

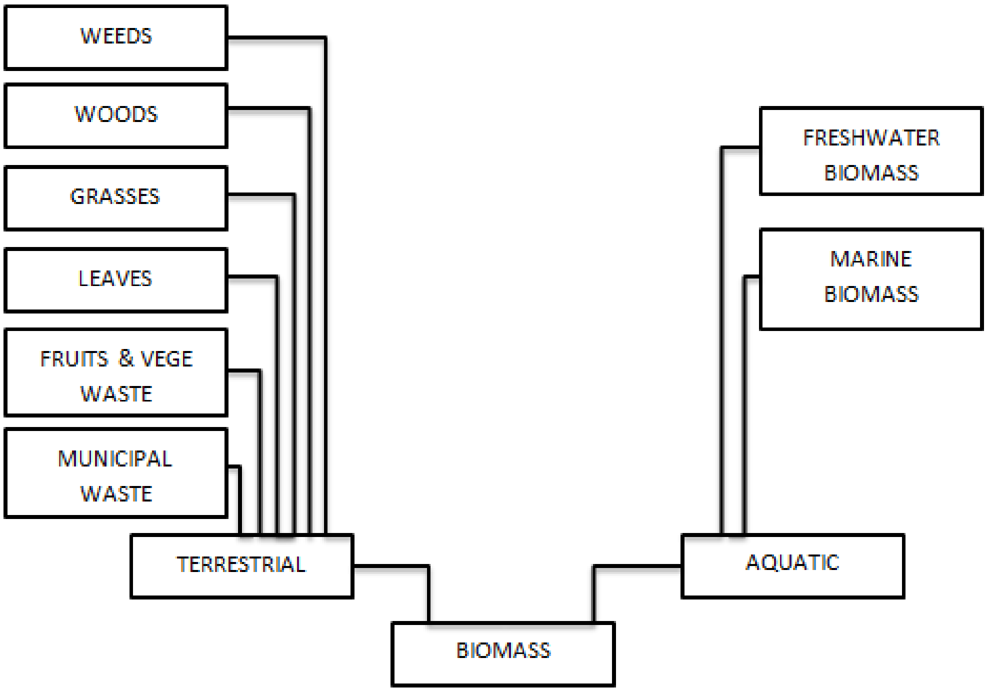

Figure 1.1 Selected types of biogas yielding biomass (Source: Gunaseelan, 1997)

Until now, there are many reports on anaerobic digestion of fruits waste consist of apple, orange, pineapple, sapota, grape, mango and banana (Banu et al., 2007), waste from pea shells (Kali and Joshi, 1995), pineapple wastes and banana peel (Bardiya et al., 1996), spoiled mango puree (Kirtane et al., 2009), combination of fruits peel waste (Srilatha et al.,1995) and banana waste (Zainol, Salihon and Abdul-Rahman, 2008). Therefore, fruits wastes have become one of the selected types of biogas yielding biomass. However, there are no present reports on anaerobic digestion and biogas production from *Benincasa hispida* wastes or also known as Kundur and the potential of the fruit have not yet been discovered.

1.2 Problem Statement

The common practice of solid waste management such as fruit and vegetable wastes from agricultural industries are mainly by dumping to the ground and also landfill. Although this kind of excesses are biodegradable and can decompose to the ground in some amount of time, however they generate unpleasant odor to the surrounding, attracting pest such as flies and contribute to an uneconomically way of living. Instead of throwing them as wastes, therefore this research is aimed at the utilization of another type of fruit wastes which is Kundur waste by anaerobic digestion for biogas generation.

1.3 Objective

There are two objectives to be achieved in this research. The objectives are:

i) To characterize the composition from Kundur waste.

ii) To identify the percentage sample compositions to produce highest volume of biogas.

1.4 Research Scope

In order to achieve the objectives, the scopes involve are:

i) Analysis of the Total Solid (TS), Total Volatile Solid (TVS), Chemical Oxygen Demand (COD), Ammonia-Nitrate, and pH using the standard method.

ii) The sample composition for sample A,B,C,D,and E are 100 wt % ,80 wt %, 60 wt %, 50wt% and 40 wt % of Kundur waste respectively with remaining wt % are cow dung as inoculum.

1.5 Significant of Study

The usage of Kundur waste as substrate for biogas production could lead to a new degree of information that wastes from this fruit also suitable as a biomass for yielding biogas. Thus, economical use is developed from another type of wastes present nowadays which is biogas that can be used for energy and also electricity. Furthermore, the residues from the anaerobic digestion of this fruit are likely to have a stabilized state and become a good biodegradable fertilizer in land that can reduce the environmental problem and nuisance.

CHAPTER 2

LITERATURE REVIEW

2.1 Definition of Biogas

Biogas is the gases that produce as a result of the action of bacteria and organic waste matter. It is a clean and renewable form of energy that could very well be a substitute for today's conventional sources of energy such as fossil fuel and oil which are not only causing ecological and environmental problems but also some additional effects to human being. Apart from that, at the same time the sources depleting at a faster rate as they are kept on consumed for energy (Santosh et al., 2004). Biogas main component are methane (CH_4) and carbon dioxide (CO_2). The biogas itself generally comprises of methane, carbon dioxide, nitrogen (N_2), hydrogen sulphide (H_2S), hydrogen (H_2), oxygen (O_2) and also ammonia (NH_3). The typical percentage composition of biogas is tabulated in Table 2.1.

Table 2.1 Typical composition of biogas.

Component	Typical analysis (% by volume)
Methane	55-56
Carbon dioxide	35-45
Nitrogen	0-3
Hydrogen suphide	0-1
Hydrogen	0-1
Oxygen	0-2
Ammonia	0-1

(Source: Balat and Balat, 2009)

2.2 Availability of Biogas Plant Worldwide

Biogas plant started from ages ago, well-known and can be found almost in every country worldwide. As in Asian country, China own millions of biogas plant but there is some doubt whether all of the biogas plant still in operation (Fischer and Krieg, 2011). This scenario is similar in India which there is millions of biogas plant in the country. These two countries are popular in most of the reported papers about biogas. However, other Asian country such as Vietnam and Thailand also own several biogas plants in their countries. Usually, the designs of the biogas plant are simple, cheap, effective and suitable for household usage. The main components to be feed into the biogas plant are mainly easy to get waste which is from the house itself and also animal dung. Apart from that, many higher institutions there occupy themselves to make research on the optimization of the efficiency for production of biogas.

As in South America, information on the anaerobic solid waste digestion is hardly to find than the anaerobic waste water treatment. Here, there are quite several efforts that had been employing in order to build and implement biogas plant but another factor that prevents them to do that is not enough of money (Fischer and Krieg, 2011). On the other hand in North America, there is strong effort on the road to the implementation of green energy although North America did not sign the Kyoto Protocol treaty which say, industrialized country will reduce their collective emissions of greenhouse gases by 5.2% compared to the year 1990 where the goal is to minimize the overall emission of the greenhouse gases (United Nations, 1998). Today, the development of the biogas plants there are still in planning and joint venture to more experienced company had been made.

Other than that, countries in Europe such as Denmark and East Germany had taken the step to build a centralized biogas plant while the West Germany is more interested in small farm scale biogas plant. The biogas plant here is highly developed as compared with other countries and there are many varieties of sizes of biogas plant operated. The growth of biogas in Europe increase 20% from the year 2006 to 2007 with Germany and United Kingdom as the biggest contributor (Rechberger, 2009). The scenario for manure, biogas crops and total biogas potential for selected countries in Europe are as in Table 2.2.

Table 2.2 Total biogas potential from crops and manure for several countries in Europe.

Country	Biogas potential from crops (Mt)	Biogas potential from manure (Mt)	Total biogas potential (Mt)
Germany	2.56	0.88	3.43
United Kingdom	1.31	0.58	1.89
Ireland	0.23	0.88	3.43
Italy	1.55	0.40	1.94

(Source: Rechberger, 2009).

2.2.1 Biogas Plant Demand in Malaysia

Malaysia is one of the countries that rich in petroleum resources mainly important in generating electricity. The energy generation in Malaysia is estimated to rise at the annual growth rate of 4.7 percent each year as illustrated in Figure 2.1.

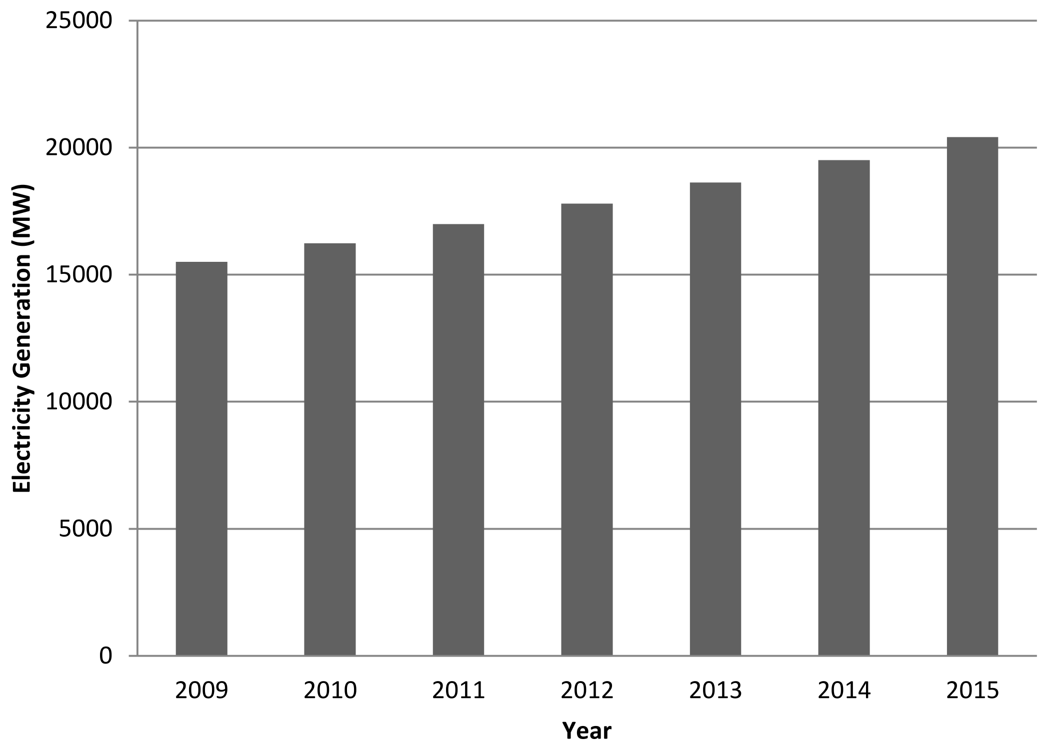

Figure 2.1 Projection of electricity generation in Malaysia based on average annual growth rate.

In the early year from 2000 to 2009, there is increase about 20% of electricity generation from 13000 MW to 15500 MW respectively (Zafar, 2011). Apart from that, the government of Malaysia had changed the Four-Fuel-Policy to the Five-Fuel-Policy in addition of the potential of renewable energy as listed in Table 2.3 to the original fuel, oil, gas, coal and hydropower under the 8th Malaysia Plan.

Table 2.3 Renewable energy sources potential in Malaysia.

Sources	Amount (MW)
Biomass	2400
Biogas	410
Solar	6500
Municipal Waste	400
Mini-hydro	500
Total	10210

(Source: Zafar, 2011).

2.3 Waste Generation in Asia

Waste can be divided into several categories that are residential, commercial, gardens, industrial, agricultural and rural, demolition and construction, transportation, water and waste water treatment plant, beaches and recreation areas, slum, fruit and vegetables market and also slaughter house. As according to the estimation and projection by the World Bank in year 1999, the municipal solid waste (MSW) in rural areas of Asian countries is increasing tremendously from year 1999 to 2025 from around 760000 ton per day to 1.8 million ton per day. The waste quantity for Asian countries up to year 2007 is tabulated in Table 2.4. Here, the MSW include the wastes generated from the domestic, industrial, commercial, institutional, demolition and construction and also municipal services (Chandrappa and Das, 2012).

Table 2.4 Waste quantity in Asian countries.

Country	MSW (kg/capita/day)
India	0.46
Bangladesh	0.49
Nepal	0.50
Philippines	0.52
Mongolia	0.60
Lao PDR	0.69
Indonesia	0.76
China	0.79
Malaysia	0.81
Sri Lanka	0.89
Thailand	1.10
Singapore	1.10
Japan	1.47

(Source: World Bank, 1999; UNDP, 2007).

In Malaysia for the year 2012, it is estimated that Peninsular alone generated around 25,000 MT of municipal solid waste daily. The percentage of the bulk is food for 48%, paper for 15%, plastic for 14% while remaining for other wastes (Waste Management Conference and Exhibition, 2012). The projection for MSW generation in Peninsular Malaysia based on average increase rate of 2.14% is shown in Table 2.5.

Table 2.5 MSW generation in Peninsular Malaysia.

State	1998	1999	2000	2010	2015	2020
Kuala Lumpur	1058	1070	1082	1202	1262	1322
Selangor	1169	1204	1240	1595	1772	1950
Pahang	202	206	210	250	270	290
Kelantan	123	126	120	87	72	42
Terengganu	119	122	125	155	170	185
N.Sembilan	267	278	291	411	471	531
Melaka	208	216	225	310	352.5	395
Johor	927	956	1005	1395	1590	1785
Perlis	28	28	29	34	36	39
Kedah	569	569	631	941	1096	1251
Penang	611	611	648	833	925	1018
Perak	719	719	763	983	1093	1012
Total	6000	6105	6369	8196	9111	9820

(Source: Tarmudi et al., 2009)

2.3.1 Agro-waste Generation in Malaysia.

Agro-waste consists of four main divisions that are animal waste, food processing waste, crop waste and hazardous toxic waste. Animal wastes as for example are manure, animal carcasses, pesticides, insecticides and also herbicides. Crop wastes include cornstalks, sugarcane bagasse, drops and culls from fruit and vegetables. On the other hand, fruit processing waste are the waste resulted from the production of processed food such as canned food, juices and beverages while the hazardous and toxic waste are the pesticides, insecticides and herbicide used in maintaining the crops in agricultural industry. Up till year 2009, 998 million ton of agricultural wastes are produce in a year worldwide while Malaysia constitute 0.12% from the total waste and disposed to landfills (Agamuthu, 2009). The total agricultural waste and projected waste generated in year 2025 base on Asian countries are listed in Table 2.6.

Table 2.6 Agro-waste generation in Asian country.

Country	Agricultural Waste Generation (kg/cap/day)	Projected Agricultural Waste Generation in 2025 (kg/cap/day)
Brunei	0.099	0.143
Cambodia	0.078	0.165
Indonesia	0.114	0.150
Laos	0.083	0.135
Malaysia	0.122	0.210
Myanmar	0.06	0.128
Philippines	0.078	0.120
Singapore	0.165	0.165
Thailand	0.096	0.225
Vietnam	0.092	0.150

(Source: Agamuthu, 2009)

Based on the Table 2.6, it can be seen that the agricultural waste generation will definitely rising for year to year as shown from the projected waste generation value based on the country, Due to that, this requires more efficient way needed to be implemented in treating the waste.

2.4 Conventional Way for Agricultural Waste Treatment

Agricultural industries in Malaysia and other countries produce huge amount of agro-waste and proper treatment need to be done. Without correct treatment , problems to human health , unpleasant odor and causing nuisance may occur. Treatment can help improve the physical properties of waste and reduce its toxicity while generating a better residue with some beneficial aspect (Sudrajat, 1990; Marchaim et al.,1991; Vermeulen et al., 1992). The conventional method that mostly use in treating agricultural waste involved open burning and also incineration.

2.4.1 Open Burning

Open burning is the combustion of waste that occurs in open area without having a smoke stack or any proper smoke management tools as for example is the burning of waste on the ground or could be in barrels. One of the effect of open burning is mainly the emissions of pollutant including soot, particulate matter, carbon monoxide, volatile organic carbon and semi-volatile organic carbon (Lemieux et al.,2004). Although open burning might cost very little amount of money, however this practice provide no benefits but harm to environment.

2.4.2 Incineration

Incineration is the process of setting fire or thermal level to destroy the waste. Waste incineration is the worst category of biomass. Providing increased waste disposal capacity worsens the waste problem by lowering the costs associated with waste generation. It also destroys resources some of which are best recycled or composted and turns them into toxic ash and toxic air emissions. Wastes that cannot be reused, recycled or composted cleanly sometime ought to be stabilized through digestion, then landfilled rather than incinerated. Incinerators also emit indirect greenhouse gases such as carbon monoxide (CO), nitrogen oxide (NOx), non-methane volatile organic compounds (NMVOCs), and sulfur dioxide (SO2) (Hogg, 2006; Rabl et al.,2007). As according to U.S. Environmental Protection Agency (EPA), U.S incinerators are among the top 15 major sources of direct greenhouse gases to the atmosphere that are listed in the US EPA's most recent inventory of US greenhouse gas emissions. This proved that although incineration process might be one of the good method for destroying potentially infectious agents however, its usage still provide bad effect to human and surrounding.